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PROGRESS REPORT ON MECHANICAL APPLICATION OF FERTILIZERS TO COTTON IN SOUTH CAROLINA, 1930[1]

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INTRODUCTION

In a comparison of methods of applying fertilizers to cotton reported in 1890 by the South Carolina Agricultural Experiment Station (*4*)[2] it was found that row fertilization was superior to broadcasting for low or medium rates of application. At about the same time the north Louisiana station (*7, p. 469–470*) planted cotton with the fertilizer placed at various depths from the surface of the soil to 8 inches below the seed. That station used two rates of application, 560 and 1,120 pounds per acre, and in both cases the highest yields were obtained when the fertilizer was placed 2 or 3 inches below the seed. Claudel and Crochetelle (*2*) showed that the concentration of salts in the soil solution that prevents germination of seeds varies with the species and that in sand moistened with a 0.5 per cent solution of the ordinary fertilizer salts, such as nitrate of soda and sulphate of ammonia, many varieties of seed fail to germinate. As a result of these and other studies, it has long been realized that, as

[1] The following contributed to a fund to cover the expenses incidental to the execution of the project: The National Fertilizer Association, Superphosphate Institute, The National Association of Farm Equipment Manufacturers, and several commercial fertilizer companies. An advisory committee in connection with the project was composed of S. H. McCrory, Bureau of Agricultural Engineering; W. H. Ross, Fertilizer and Fixed Nitrogen Investigations, and J. J. Skinner, Soil Investigations of the Bureau of Chemistry and Soils, U. S. Department of Agriculture: H. W. Barre, Director of the South Carolina Agricultural Experiment Station, and H. R. Smalley, Director, Soil Improvement Work, National Fertilizer Association, representing the joint committee on fertilizer application. The authors are indebted to E. E. Hall, J. A. Riley, and C. S. Patrick, of the Pee Dee, Sand Hill, and Clemson College Agricultural Experiment Stations, S. C., respectively, for assistance in connection with the field work.

[2] Italic numbers in parentheses refer to Literature Cited, p. 31.

a general rule, seed and fertilizers should not be planted in contact, and it was believed that fertilizers should be placed in a band 2 or 3 inches below the seed for best results.

A common practice is to apply the fertilizer in an open furrow and cover it with several inches of soil a week or 10 days prior to planting the cottonseed. The settled seed bed is usually dragged down somewhat immediately before planting. While the seed is supposedly located 2 inches or more above the fertilizer, it is probable that in many cases the fertilizer and seed are either in close proximity or in contact. Early experimental results, the adaptability of the available tools, and the desire to distribute labor over a long period no doubt are responsible for the establishment and continuation of the practice. A practice similar except that the fertilizer is applied immediately before planting, is also followed.

Poor germination has frequently been attributed to adverse weather and soil conditions and to poor seed. The location of the fertilizer with respect to the seed, which may be responsible for many failures to obtain satisfactory stands of cotton and greatest return from the fertilizer applied, apparently has not been given due consideration.

Recent studies and developments indicate that practices may be improved in the interest of greater efficiency. Musgrave and Coe (*5*, *6*) reported that germination and yields were very poor when the fertilizer was in contact with or immediately below the seed. Not only stand but yields were best when the fertilizer was placed at the sides of the seed.

In the trend toward labor-saving equipment, combination planters and fertilizer distributors recently have been introduced which apply the fertilizer and plant the seed simultaneously. These machines, differing greatly in design, place the fertilizer in various positions in relation to the seed. Realizing that the efficiency of available distributors differed greatly and was determined by various operating characteristics in addition to fertilizer placement, a cooperative study (*3*) of 22 representative fertilizer distributors for cotton was conducted in South Carolina during 1929. From this study it was evident that the most striking differences in germination and yield were due to the variability of distribution and placement of the fertilizer.

As a continuation of this project the joint committee on fertilizer application,[3] in cooperation with Clemson Agricultural College and Experiment Station, and the Bureau of Chemistry and Soils and the Bureau of Agricultural Engineering of the United States Department of Agriculture, undertook, a study of methods of applying fertilizer to cotton. The experiments in 1930 were conducted in South Carolina at the Pee Dee Experiment Station, Florence, on Ruston fine sandy loam; at the Sand Hill station, Columbia, on Norfolk coarse sand; and at Clemson College on Cecil sandy clay loam. In order that the experiments might be extensive and the methods of application reproducible with field equipment, the fertilizer and seed were applied by machine rather than by hand. The purpose of the study was to secure fundamental information which would serve as a basis for the development of more efficient distributing machines and the

[3] The joint committee on fertilizer application is composed of representatives of the American Society of Agronomy, American Society of Agricultural Engineers, National Association of Farm Equipment Manufacturers, and the National Fertilizer Association.

recommendation of more effective and safer methods of fertilizer application at planting time for cotton.

FERTILIZERS

Standard 4–8–4 mixed fertilizer was used in the main part of the experiments. A more concentrated fertilizer of 8–16–8 grade was also used in certain tests. These fertilizers were prepared in the Bureau of Chemistry and Soils from the ingredients shown in Table 1. An additional quantity of the 8–16–8 fertilizer was required for completion of the experiments, and a commercially prepared fertilizer was purchased, which upon analysis was shown to be a 5–15–4 mixture.

TABLE 1.—*Materials used in fertilizer mixtures* [1]

Ingredient	Composition of material			Quantity in mixture—	
	N	P_2O_5	K_2O	4–8–4	8–16–8
	Per cent	*Per cent*	*Per cent*	*Pounds per ton*	*Pounds per ton*
Nitrate of soda	15.66			128	341
Sulphate of ammonia	20.45			196	
Leunasalpeter	25.89				129
Cottonseed meal	7.11	2.51	1.68	281	281
Ammophos	10.81	48.91			494
Superphosphate	16.72			915	
Precipitated bone		40.00			179
Sulphate of potash			48.90	154	327
Sulphate of magnesia					114
Sulphate of manganese					20
Filler, soil				326	115

[1] Analyses made by F. O. Lundstrom, Assistant Chemist, Bureau of Chemistry and Soils.

Part of the phosphoric acid for the 8–16–8 fertilizer was supplied in the form of precipitated bone because this material also contains lime. Epsom salt and hydrated manganous sulphate were also added in sufficient quantity to make 0.9 per cent magnesium oxide and 0.3 per cent manganese oxide or double the quantities of these materials in the 4–8–4 mixture. Thus both fertilizers contained the same elements.

It was considered possible that lack of uniformity in the composition of the fertilizer or segregation during distribution might have some effect upon the crop. While most ordinary commercial mixtures would not segregate to a noticeable extent in the type of distributor used in this study, it was nevertheless decided to eliminate this variable. Therefore, the bulk of the 4–8–4 and all of the 8–16–8 mixture were made by a special graining process. A 4–8–4 mixture, composed of the same ingredients as the grained 4–8–4, was also prepared in the usual manner by dry mixing.

The grained material was produced in 100-pound batches by the following method: Weighed quantities of the finely powdered ingredients were thoroughly dry mixed and then sprayed with water in a drum mixer and afterwards grained at a temperature of 105° F. in standard equipment. This treatment caused the water-soluble salts to crystallize upon the insoluble particles, cementing them together and thus building up granules each of which contained all of the fertilizing elements. The grained product was sieved to sizes of 10–30 and 5–8 mesh. The oversize material was crushed and sieved and the

accumulated fines were regrained until all of the material originally mixed was made up into the desired sizes of particles. The entire lot of each fertilizer mixture was thoroughly remixed prior to sacking in moisture-proof bags. Small samples from various parts of the mixtures were analyzed and the results showed that the grained products were homogeneous throughout.

The results of chemical analyses and drillability measurements made upon the fertilizers are given in Tables 2 and 3.

TABLE 2.—*Chemical analyses of the fertilizers* [1]

Fertilizer	Total N	Total P_2O_5	Available P_2O_5	K_2O	H_2O
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
4–8–4 grained 10–30 mesh	4.25	8.21	8.01	4.29	1.86
4–8–4 grained 5–8 mesh	4.17	8.02	7.81	4.28	1.69
4–8–4 dry mixed	4.16	8.45	8.24	3.91	1.84
8–16–8 grained 10–30 mesh	8.51	17.49	16.87	8.16	2.56
5–15–4 commercial	5.42	15.35	14.67	4.46	2.19

[1] Made by F. O. Lundstrom.

TABLE 3.—*Physical measurements of the fertilizers*

Fertilizer	Apparent specific gravity	Angle of repose	
		First [1]	Second [2]
		Degrees	*Degrees*
4–8–4 grained 10–30 mesh	1.07	38	39
4–8–4 grained 5–8 mesh	1.09	37	42
4–8–4 dry mixed	1.07	40	39
8–16–8 grained 10–30 mesh	1.03	38	38
5–15–4 commercial	1.09	----------	41

[1] At time of manufacture. [2] After last planting.

SEED

Coker Super Seven cottonseed of high germination were used in the tests at the Pee Dee and Sand Hill stations. The seed were delinted with sulphuric acid and, after drying, imperfect and gin-cut seed were removed by hand picking to further improve the viability of the seed.

Acid-delinted Dixie Triumph seed of high germination were used at Clemson College. All lightweight seed were floated off after the seed were delinted.

In all cases the seed were planted at the rate of approximately 1 bushel per acre.

EXPERIMENTAL DISTRIBUTOR

In the present study, for both the fertilizer and seed, it was particularly important that any variations in application rates, placements, distribution along the row, and coverage be reduced to an insignificant minimum. In order to obtain uniform conditions and to obviate the difficulties resulting from variable and uncontrollable factors among commercial distributors, only one special combination machine, which applied the fertilizer and planted the seed simultaneously, was used for all of the tests. The machine was of the 4-wheel type, having a revolving-cylinder top-delivery fertilizer distributor and a cell-plate

planter. The top-delivery type of distributor was selected because its operation is least affected by changing conditions.

The functions of the experimental machine were: Opening the furrows, applying the fertilizer, forming a raised seed bed over the fertilizer, and planting and covering the seed. Although the machine itself was under development and in some respects lacked refinement, its performance was satisfactory. The performance of the machine in the field and laboratory was determined by the same methods as described in the report (*3*) of last year's work.

FERTILIZER PLACEMENTS

Sixteen different placements of fertilizer were used in which the total fertilizer application was made at planting time. The shapes of the fertilizer bands and their relative positions with respect to the seed are shown in Figures 1 and 2 by sketches representing a cross section of the seed bed. Placements Nos. 17 and 18 were split applications where one-half of the fertilizer was applied in a band below the seed at planting and one-half in bands to each side of the row at time of thinning.

Attachments for the distributor were developed to obtain the desired placements of the fertilizer. The exact size and shape of the bands and degree of mixing with the soil were determined to some extent by the tools available for the attachments and by certain features of design of the machine.

For placing the fertilizer in direct contact with the seed, the delivery tubes were attached at the rear of the seed shoe. The bands of fertilizer below the seed having average widths of 1.75 and 3.25 inches were obtained by opening furrows with 2-inch and 3.75-inch elongated cultivator shovels having shields attached for excluding the soil from the furrow until the fertilizer had been deposited. It will be noted that the fertilizer was applied more heavily at the center than at the sides. This kind of band is similar to that obtained with standard equipment.

For placing the fertilizer in bands at the sides of the seed, two standard single-disk furrow openers were used. The width of band was determined by the angle at which the disks were mounted.

Where the fertilizer was mixed with the soil below the seed, the fertilizer was first deposited in a furrow, opened by the 3.75-inch shovel above described, at a depth 3 inches below the point at which the seed was to be deposited. A 2-inch shovel the upper half of which had been narrowed to 0.75 inch then followed, lifting a large portion of the fertilizer and mixing it with the soil.

The shape of the fertilizer bands and their position with respect to the seed were determined by careful examination during (1) the development of the attachments, (2) the actual tests, and (3) special tests. Observations were made on horizontal and both cross-sectional and longitudinal vertical planes.

The relative placement of fertilizer and seed was subject to little variation. Noticeable variations occurred when the machine was not traveling directly forward, was passing over uneven ground, or upon striking obstructions. Such variations during these tests were infrequent and should have no significant effect on the results.

The sword furrow opener for the seed was equipped with effective depth gauges and fenders insuring uniform depth of planting. The

seed were planted approximately 1 inch deep except on the sandy clay loam soil where the depth of planting was slightly less than 1 inch. The cell-plate planter distributed the delinted seed quite regularly.

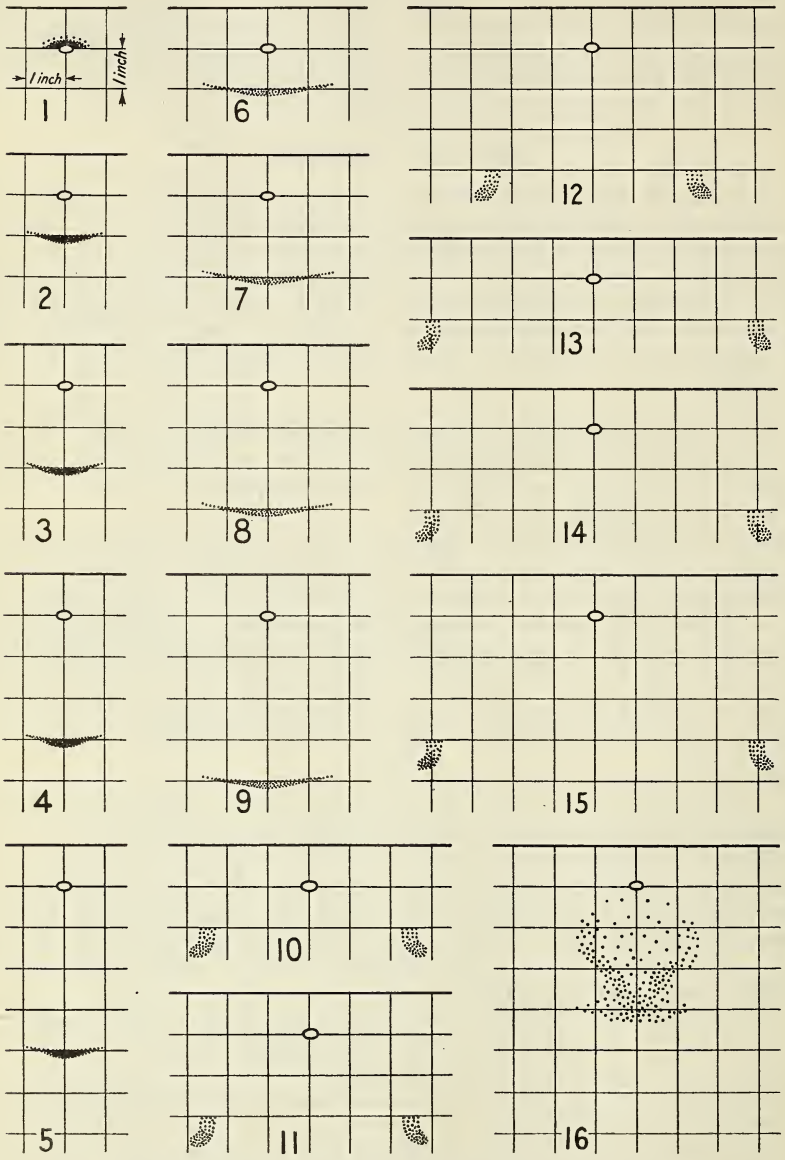

FIGURE 1.—Placement of fertilizer in relation to the seed at the time of planting

The seed were planted in loose soil broken up by the special shovels previously described, except where the fertilizer was placed at the sides of the seed. In placing the fertilizer at the sides of the seed that part

of the seed bed between the disks was left undisturbed and the seed were planted in firm soil except at the 3-inch depths below the level of the seed in which case the disk hanger was carried low enough to disturb the seed bed.

APPLICATION RATE

The average application rates obtained during the experiment are given in Table 4. For any particular adjustment of the machine the delivery or application rate depends upon the apparent specific gravity of the fertilizer and the slippage of the drive wheel. The machine was not equipped with sufficient gears to provide minute changes near the limits of the delivery range. Thus the same relative

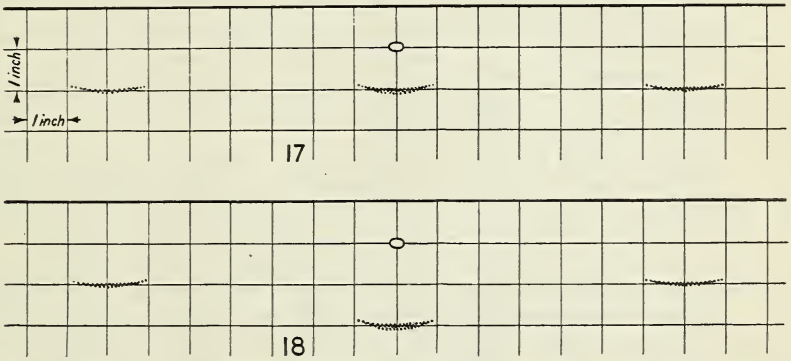

FIGURE 2.—Placement of fertilizer below the seed at planting and at the sides of the row at thinning

adjustments were used throughout the experiment for the five fertilizers and three soil types. As a result, the average rates of application differ slightly according to the apparent specific gravities of the fertilizers and all rates are somewhat higher for the sandy clay loam soil due to less wheel slippage. The experiment, however, was designed primarily to measure certain relative effects of each fertilizer for each soil type, and the application rate was accurately maintained in all of the tests made with the same fertilizer on the same soil.

TABLE 4.—*Fertilizer application rates determined by distributor calibrations*

Fertilizer	Description of rate	Quantity applied in—	
		Fine sandy loam and coarse sand	Sandy clay loam
		Pounds per acre	*Pounds per acre*
4-8-4, grained (10-30 mesh)	Standard	787	804
Do	One-half rate	394	403
4-8-4, grained (5-8 mesh)	Standard	806	823
4-8-4, dry mixed	do	785	802
Do	One-half rate	393	401
8-16-8 grained (10-30 mesh)	do	189	193
Do	Standard	381	389
Do	1½ rate	565	577
5-15-4 dry mixed (commercial)	One-half rate	194	198
Do	Standard	407	416
Do	1½	608	621

The relative rates for any fertilizer were definitely established by gear ratios. This is substantiated by numerous tests in which the variance of measured and theoretical rates did not exceed the experimental error. The lowest rate for the 8–16–8 and 5–15–4 fertilizers may appear to be an exception but the difference was due to the lack of proper gears to obtain exactly the desired ratio.

The minor deviations in the application rate of each fertilizer throughout any series of tests resulted either from the compacting of the fertilizer in the hopper during filling and operation, or to changes in the wheel slippage. The tests show a small but gradual increase in delivery rate as the hopper is emptied. Shaking the hopper at the time of filling insured a more uniform settling of the fertilizer and greatly reduced compacting during operation. The average percentage deviation in application rates for the six 124.5-foot rows which were planted for individual tests was practically the same for all fertilizers and averaged 0.89. A part of the deviation may be attributable to experimental error in obtaining the data, and it is therefore evident that rates of application for any fertilizer were accurately maintained during individual tests.

For convenience of discussion, the standard application rate of the 4–8–4 fertilizers will hereafter be considered as 800 pounds per acre and the rates for the 8–16–8 and 5–15–4 fertilizers as 200, 400, and 600 pounds per acre for all soils, instead of the actual application rates for each fertilizer on the different soils as given in Table 4.

Variations in wheel slippage were reduced by having a uniform and level seed bed and effective angle-iron lugs on the drive wheel. The average per cent wheel slippage recorded for each soil type is as follows: Fine sandy loam 17.1 $\pm$0.08; coarse sand 17.1 $\pm$0.05; sandy clay loam 15.1 $\pm$0.07. Variation in wheel slippage on each soil as indicated by the probable error was negligible.

IRREGULARITY OF DISTRIBUTION

The degree of variability of distribution of the fertilizer was determined from successive 1-foot intervals over a distance of 38 feet in the laboratory and is assumed to closely represent the distribution in the field. The features of design of the dispensing mechanism are such as to give comparatively uniform delivery of a free-flowing fertilizer. A range comprising five degrees of irregularity, which is representative of the usual operation of various types of commercial distributors, was used for one phase of the study in addition to normal distribution. The degree of variability of distribution, as indicated by the maximum and minimum deliveries per foot and the coefficient of variation, is given in Table. 5.

TABLE 5.—*Variability of fertilizer distribution*

Degree of variability	Delivery					
	Mean[1]		Maximum	Minimum	Standard deviation	Coefficient of variation
	Pounds per acre	*Grams per foot*	*Grams per foot*	*Grams per foot*	*Grams per foot*	*Per cent*
10–30 MESH, GRAINED 4–8–4						
Normal	388	14.13	17.1	10.9	1.364	9.7
Do	806	29.36	37.7	23.0	3.106	10.6
First	779	28.38	40.5	20.2	5.287	18.6
Second	777	28.33	42.2	17.8	6.702	23.7
Third	802	29.23	52.8	5.8	13.358	45.7
Fourth	782	28.50	53.2	4.5	15.399	54.0
Fifth	787	28.68	55.9	4.6	17.574	61.3
DRY MIXED 4–8–4						
Normal	398	14.49	21.2	11.7	2.134	14.7
Do	775	28.25	33.7	24.0	2.522	8.9
First	754	27.47	48.4	13.1	10.292	37.5
Second	769	28.04	51.6	12.1	12.240	43.7
Third	781	28.46	56.5	5.3	15.651	55.0
Fourth	784	28.58	61.1	5.8	16.212	56.7
Fifth	789	28.74	61.2	4.5	18.064	62.9
10–30 MESH, GRAINED 8–16–8						
Normal	184	6.69	9.4	4.7	.995	14.87
Do	376	13.70	16.3	11.2	1.252	9.14
Do	563	20.52	24.9	16.4	1.894	9.23
COMMERCIAL, DRY MIXED 5–15–4						
Normal	206	7.49	9.0	6.1	.693	9.25
Do	409	14.91	18.3	11.7	1.395	9.4
Do	615	22.41	29.3	17.0	2.397	10.7

[1] Mean deliveries vary somewhat because they are calculated from small samples, and high or low deliveries per foot appear at the beginning and end of the tests by chance.

The selected degrees of irregularity were obtained by diverting the normal flow of fertilizer from the hopper into a circular chamber in which a horizontal paddle wheel pushed the fertilizer over a discharge opening. The form of this opening was determined by interchangeable plates designed to give a variable flow in a cyclic manner. By changing the shape of the opening different degrees of variation in flow were obtained. The length of delivery cycle determined by the speed of the paddle wheel remained unchanged at 5.35 feet travel of the machine. Figure 3 shows representative delivery curves for the 10–30 mesh 4–8–4 fertilizer.

FIELD TESTS

PLAN OF EXPERIMENTS

Although placement of fertilizer in relation to the seed received major attention, some consideration was given to the effect of irregular distribution, size of fertilizer particle, concentration of the fertilizer, and split applications. The criteria upon which relative efficiencies were based are germination and yield.

The three locations selected for the experiment offered an opportunity to study the reaction of cotton to fertilizer treatment by various methods on three widely different soils. Uniformity of soil was a consideration in selecting the plats. The ground was broken

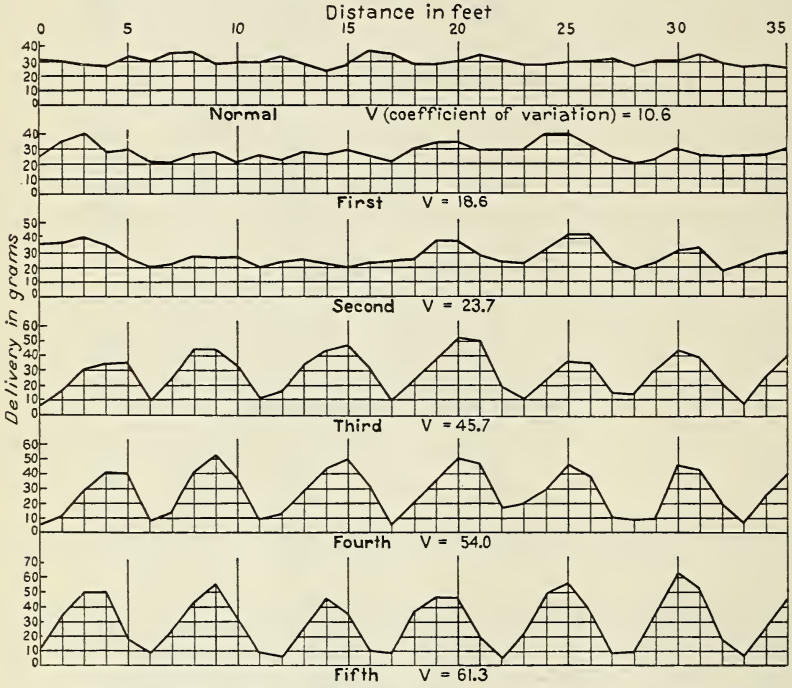

FIGURE 3.—Representative curves showing distribution of 787 pounds per acre of 10–30 mesh, grained 4–8–4 fertilizer for selected degrees of irregularity

and permitted to settle before planting started. Precautions were taken to have uniform, firm, and level seed beds and straight rows which are prerequisites to accurate machine work, particularly for placement of the fertilizer in relation to the seed. Rows 124.5 feet in length were marked off 3½ feet apart. Each plat consisted of one row and thus had an area of one-hundredth acre.

The various placements and treatments in the main portion of the experiment were planted in single rows, in the same order in different series. Six series were planted at the Pee Dee station, six at the Sand Hill station, and five at Clemson College. This procedure located replications at definite intervals throughout the field.

In planting the seed on the unfertilized rows the soil was first stirred with a 2-inch shovel to a depth of 3 inches.

COLLECTION OF DATA

Observations were made on two 50-foot lengths in each row, 12¼ feet at each end of the 124.5-foot row being discarded. Thus each figure shown for the fine sandy loam (Pee Dee station) and coarse sand (Sand Hill station) represents the average of 12 observations, while those shown for the sandy clay loam soil (Clemson College station) represent an average of 10 observations.

GERMINATION

SOIL MOISTURE

Attention is called to the climatic and soil-moisture conditions prevailing at time of and following planting for the three soils. The rainfall is shown in Table 6. The total for the period was less than normal at each of the stations. Planting on the fine sandy loam was made April 22 and 23 as soon as advisable following good rains which fell on April 19 and 20. The soil contained 9.9 per cent moisture at time of planting. No rain of consequence fell until May 14. Under these unfavorable conditions many seeds which germinated failed to break through the surface of the ground as the soil dried out rapidly. Other seeds which did not sprout until the soil became too dry for germination remained in the soil in good condition and germinated following the rain on May 14.

TABLE 6.—*Rainfall during the cotton growing season*

DAILY RAINFALL DURING GERMINATION PERIOD[1]

Period	Pee Dee station		Sand Hill station		Clemson College station	
	1930	Normal	1930	Normal	1930	Normal
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
May 8					0.70	
9			0.45			
11					.81	
12			.04		.45	
13	0.04				.33	
14	1.33		1.90		.84	
15	.05					
17					.07	
18					.16	
19					.07	
23					.45	
24			.29			
Total	1.42		2.68		3.88	

MONTHLY RAINFALL DURING GROWING SEASON

April	2.42	3.25	1.15	2.89	2.91	3.93
May	1.42	4.65	2.68	3.09	3.88	3.94
June	3.51	5.31	5.25	4.17	5.66	4.85
July	2.69	5.69	4.68	5.35	3.64	5.27
August	3.61	3.79	1.34	5.47	1.31	5.00
September	4.35	5.11	4.35	3.45	1.33	4.10
Total	18.00	27.80	19.45	24.42	18.73	27.09

[1] Includes all rainfall from date of planting to last germination count.

The 2.6 per cent moisture content of the coarse sand at time of planting on April 28 and 29 was too low for germination of the cottonseed and germination did not occur until following the rain of May 9. This rain was followed by a heavy rain on May 14. Moisture conditions were rather favorable for this soil at time of germination.

Although the moisture content of 5.03 per cent for the sandy clay loam at the time of planting on May 1 and 2 was too low for germination, the seed remained in the ground in good condition until the rain of May 8. This rain was ample for germination of the seed. Rains followed on May 11, 12, 13, and 14. Under these conditions of ample moisture content at time of germination no injury to germination from fertilizer applied in any reasonable manner would be expected on this comparatively heavy soil.

The rather high probable errors for the germination records shown on May 13 on the sandy clay loam are due to the very rapid rate at which plants broke through the ground during the day. Very few plants were showing on the entire field at noon on May 12. A shower in the late afternoon removed the slight ridge of soil left by the press wheel of the planter and exposed the crooks of many plants. Counting was begun early on May 13 and was not completed until late afternoon. In many cases at least one-third of the plants counted in the late afternoon had pushed through the surface during the day, due to the bright sun and favorable moisture conditions. Results are comparable, however, as each series was counted in regular order.

PLACEMENT

Germination records for 16 different placements of the 4–8–4 fertilizer applied at the rate of 800 pounds per acre are shown in Table 7. The 10–30 mesh grained fertilizer was used on the fine sandy loam while the dry-mixed material was applied on the coarse sand and sandy clay loam soils. Severe injury to germination as measured by the number of plants appearing above ground occurred where the fertilizer was placed in immediate contact with the seed on all three soils, but was particularly severe on the fine sandy loam and coarse sand.

TABLE 7.—*Number of cotton plants appearing above the ground per 50-foot row for various placements of 800 pounds per acre of 4-8-4 fertilizer*

No.	Fertilizer placement: Description	Ruston fine sandy loam (planted Apr. 22): May 1	Ruston fine sandy loam (planted Apr. 22): May 5	Ruston fine sandy loam (planted Apr. 22): May 21	Norfolk coarse sand (planted Apr. 28): May 13	Norfolk coarse sand (planted Apr. 28): May 19	Norfolk coarse sand (planted Apr. 28): June 2	Cecil sandy clay loam (planted May 2): May 13	Cecil sandy clay loam (planted May 2): May 16	Cecil sandy clay loam (planted May 2): May 27
	No fertilizer	303±11	398± 9	416± 6	298±17	488±12	493±11	177±18	465± 5	479±3
1	In contact with seed	1± .2	10± 1	22± 1.3	.3± .2	11± 1.7	19± 2.3	.7± .2	6± 1	58±6
2	1.75-inch band 1 inch below seed	8± 1.7	27± 4	63± 4	14± 1.9	72±11	98±12	117±23	398± 8	428±6
3	2 inches below seed	35± 6	107±17	128±12	16± .8	75± 6	89± 9	172±17	455± 3	461±4
4	3 inches below seed	126± 7	188±10	213± 7	46± 7	244±16	238±14	215±10	445± 5	463±4
5	4 inches below seed	135± 7	262± 7	367± 8	263±17	450± 7	462±10	(1)		
6	3.25-inch band 1 inch below seed	18± 3	82±10	132±11	6± 1.6	66± 8	163±16	178±21	411± 8	456±5
7	2 inches below seed	31± 6	132±14	193±14	7± 1.9	90± 8	108± 6	200±18	444± 5	447±4
8	3 inches below seed	84± 8	155±14	232±10	20± 4	200±17	238±18	246±23	453± 4	466±4
9	4 inches below seed	121± 5	242± 7	419± 5	273±13	459± 7	469± 6	(1)		
	Bands 2.25 inches to each side:									
10	1 inch below level of seed	332± 8	419± 5	435± 4	302± 9	455± 9	484± 5	209±18	443± 7	466±4
11	2 inches below level of seed	345± 6	419± 5	457± 3	284±12	458± 8	445± 6	237±18	454± 7	470±6
12	3 inches below level of seed	193± 8	247±10	413± 6	273±15	393± 8	448± 8	199±16	456± 3	459±2
	Bands 3.75 inches to each side:									
13	1 inch below level of seed	322± 8	433± 8	433± 6	254±14	462± 9	490± 9	171±18	474± 6	487±4
14	2 inches below level of seed	331±11	423±11	446±10	290±14	462± 1.3	507±11	187±16	473± 9	487±2
15	3 inches below level of seed	277±10	348±11	429±11	401±11	502± 8	527± 6	205±16	473± 8	494±5
16	Mixed with soil below seed	20± 3	88± 5	175± 5	45±10	213±13	206±14	215±13	447±71	456±3
17	One-half placement No. 2 / One-half side dressed [2]	19± 2.7	86± 8	181± 6	70±15	242±29	288±24	(1)		
18	One-half placement No. 3 / One-half side dressed [2]	53± 9	169±17	251±16	71±11	192±16	258±18	(1)		

[1] Tests were not conducted.

[2] Side dressed at thinning in bands 1.75 inches wide at a depth of 2 inches and 6 inches to each side of the row.

It will be observed that germination was affected quite similarly on the fine sandy loam and coarse sand. Considering the group in which placement of fertilizer was in a 1.75-inch band at different depths below the seed on these soils, the following facts are evident. The number of plants appearing aboveground was greatly reduced at the 1-inch depth; the stands were not satisfactory at the 2-inch depth due to the small number and irregular distribution of plants along the row; stands were fairly satisfactory at the 3-inch depth and entirely satisfactory at the 4-inch depth. These differences are illustrated in Figures 4 and 5. Appearance of the plants aboveground was considerably delayed, even with the deeper placements, particularly on the fine sandy loam. While there was delay in germination

FIGURE 4.—Cotton planted April 22, photographed May 17 on Ruston fine sandy loam at Florence, S. C., fertilized with 800 pounds per acre of a 4–8–4 mixture applied in a 1.75-inch band as follows: *a*, No fertilizer; *b*, in contact with seed; *c*, 1 inch below seed; *d*, 2 inches below seed; *e*, 3 inches below seed; *f*, 4 inches below seed

on the coarse sand where the fertilizer was applied at the 3-inch depth, practically no delay was noted at the 4-inch depth.

For the fertilizer placement in a band 3.25 inches wide at different depths below the seed on both the fine sandy loam and coarse sand, unsatisfactory stands were obtained at the 1-inch depth, the stand for the 2-inch depth was such that many farmers would have plowed up the cotton and replanted as the plants were not well distributed along the rows, the stand at the 3-inch depth was fairly satisfactory, and that at the 4-inch depth was entirely satisfactory. Considerable delay in the appearance of plants aboveground occurred even with the deeper placements, but it was not appreciable for the 4-inch depth on the coarse sand.

Satisfactory stands were obtained at all depths and distances from the seed when the fertilizer was applied at the sides of the seed. Some delay in plants appearing above the ground was noted on the fine sandy loam where the fertilizer was applied at the sides of the seed at the 3-inch depth, although at the other depths plants appeared

above the ground more rapidly than on the unfertilized rows. When the disk openers were set to give the placement at the 3-inch depth the disk hanger disturbed the soil lying between the disks where the seed was planted. This was especially true where the fertilizer was applied 2.25 inches to each side of the seed. It is likely that delay in germination occurring where the fertilizer was applied at the sides of the seed at the 3-inch depth was due in part to the stirring of the soil in which or on which the seed was planted.

It would seem that applying the fertilizer in bands at the sides of the seed, in addition to the fact that so located there is probably less movement of soluble fertilizer salts in the direction of the seed, offers the advantage of planting the seed in firm soil. Many farmers have long believed it desirable to plant cotton on a well settled seed bed and have bedded on the fertilizer 10 days or two weeks before planting in order to produce this condition.

FIGURE 5.—Cotton planted April 28, photographed July 9, on Norfolk coarse sand near Columbia, S. C., fertilized with 800 pounds per acre of a 4–8–4 mixture applied in a 1.75-inch band as follows: *a*, No fertilizer; *b*, in contact with seed; *c*, 1 inch below seed; *d*, 2 inches below seed; *e*, 3 inches below seed; *f*, 4 inches below seed

Stands were not satisfactory on the fine sandy loam or coarse sand where the fertilizer was mixed with the soil. (Fig. 6, A.)

Stands were hardly satisfactory on these soils where one-half of the fertilizer was applied at planting in a 1.75-inch band 1 inch below the seed, although the stands were fairly satisfactory where one-half of the fertilizer was applied at planting in a 1.75-inch band 2 inches below the seed.

All methods of application resulted in satisfactory stands on the sandy clay loam with the exception of the placement where the fertilizer was applied in immediate contact with the seed. A slight delay in appearance of plants above the ground occurred where the fertilizer was placed in a band 1.75 inches wide 1 inch below the seed.

RATE OF APPLICATION

Increasing the rate of application of 8–16–8 fertilizer from 200 to 400 and 600 pounds per acre on the fine sandy loam resulted in unsatisfactory stands where the heavier amounts were applied in

bands 1.75 inches wide and 2 inches below the seed, and where the fertilizer was mixed with the soil, as shown in Table 8. Entirely satisfactory stands were obtained with all rates of application used where the fertilizer was applied in bands 2.25 inches to each side and 2 inches below the level of the seed, and is illustrated in figure 6, B.

FIGURE 6.—Cotton planted April 22, photographed May 17, on Ruston fine sandy loam with 8–16–8 fertilizer applied as follows: A.—Mixed with the soil below the seed: *a*, 200 pound per acre; *b*, 400 pounds per acre; *c*, 600 pounds per acre. B.—Bands 2.25 inches to each side of and 2 inches below the level of the seed: *a*, 200 pounds per acre; *b*, 400 pounds per acre; *c*, 600 pounds per acre

On the coarse sand increasing the application of 5–15–4 fertilizer from 200 to 400 and 600 pounds per acre resulted in poor stands with the heavier applications where the fertilizer was applied in 1.75-inch bands 2 inches below the seed. Fairly satisfactory stands were obtained even with the heavier applications where the fertilizer was mixed with the soil. Entirely satisfactory stands were obtained with all rates where the fertilizer was applied in bands 2.25 inches to each side of and 2 inches below the level of the seed.

TABLE 8.—*Number of cotton plants appearing above the ground per 50-foot row for different placements and rates of application of 8-16-8 and 5-15-4 fertilizers*

Fertilizer placement	Fertilizer application rate per acre	Ruston fine sandy loam, grained 8-16-8 fertilizer			Norfolk coarse sand, commercial 5-15-4			Ceeil sandy clay loam, commercial 5-15-4		
		May 2	May 6	May 22	May 14	May 20	June 2	May 13	May 16	May 27
	Pounds									
	No fertilizer	276±11	356±13	442± 8	495± 4	462±11	472± 7	177±17	446± 6	483±6
1.75-inch band, 2 inches below seed	200	71± 9	176±14	271±12	134±21	259±21	235±20	182±16	442± 5	469±5
Do	400	49± 7	106±12	141±17	36± 9	88± 9	97± 9	207±17	458± 6	479±5
Do	600	8± 1.2	27± 4	98±14	54±15	95±14	94±15	216±17	449±16	482±4
Bands, 2.25 inches to each side, 2 inches below level of seed	200	286±14	343±12	389± 7	486± 7	481± 7	504±10	257±18	469± 8	492±5
Do	400	266±15	323± 3	407± 6	480± 5	488± 6	467± 4	234±20	458±20	481±3
Do	600	307±12	365±12	405± 9	450± 7	431±12	442±11	282±21	453± 6	486±2
Mixed with soil below seed	200	58± 5	166± 8	281± 7	169±18	323±17	332±10	289±17	455± 8	464±4
Do	400	23± 4	63± 6	179± 9	144±27	213±23	256±19	279±20	454± 9	487±8
Do	600	5± .7	23± 4	114± 8	42± 8	186±12	243±14	261±18	449± 5	466±4

Increasing the rate of application of 5–15–4 fertilizer from 200 to 400 and 600 pounds per acre with the three methods used resulted in no appreciable effect on stands on the sandy clay loam soil.

The relative effects of 400 and 800 pounds per acre of 4–8–4 fertilizer on germination for bands below the seed may be noted by comparing placements Nos. 2 and 3 with Nos. 17 and 18 in Table 7.

IRREGULAR DISTRIBUTION

Irregular distribution of fertilizer of the varying degrees used resulted in no significant differences in germination on the fine sandy loam or coarse sand, although higher germination was obtained where the fertilizer was distributed irregularly than where applied uniformly along the row. (Table 9.) The plants, however, were not as uniformly spaced where the fertilizer was irregularly distributed. Although many plants appeared on the rows where the fertilizer was distributed in cycles, there was a tendency for these plants to be found in groups roughly corresponding to the low point in the cycle of delivery. From the standpoint of production, this situation would be undesirable, as most of the plants would be a considerable distance from the areas where the larger quantities of fertilizer were applied. It should be borne in mind that the placement used in this study—a band 1.75 inches wide placed 2 inches below the seed— proved to be unsatisfactory as far as germination is concerned under the conditions that prevailed at these stations.

TABLE 9.—*Number of cotton plants appearing above ground per 50-foot row for different degrees ofirregular distribution of 800 pounds per acre of 4–8–4 fertilizer applied in 1.75-inch band 2 inches below the seed*

Coefficient (*V*) of variability of fertilizer distribution [1]	Ruston fine sandy loam			Norfolk coarse sand			Cecil sandy clay loam		
	May 2	May 6	May 22	May 14	May 20	June 2	May 13	May 16	May 27
No fertilizer	242±11	332±14	416± 5	503± 5	488± 8	472± 9	211±22	445±7	488±3
10	35± 6	107±17	128±12	46± 7	119±12	124±11	172±17	455±3	461±4
17	26± 4	76± 8	168± 6	56± 8	126±11	134±11	(2)	-------	-------
24	30± 4	75± 6	192± 8	136±25	173±22	204±24	(2)	-------	-------
45	29± 6	86±11	184± 7	79± 9	177±12	169±11	124±12	474±5	476±8
55	(2)	-------	-------	118±16	168±11	201±14	138±11	481±4	476±9
62	34± 5	96± 9	188± 8	74±12	168±12	175±10	112±11	487±5	484±8

[1] Based on 1-foot intervals. [2] Tests were not conducted.

While irregular distribution of the fertilizer did not adversely affect the final germination on the sandy clay loam there was indication of a slight, though unimportant, delay in germination with the more irregular distributions.

SIZE OF PARTICLE

The finer-sized particles of fertilizer apparently were of advantage in promoting germination on the fine sandy loam, while the medium-sized particles resulted in the largest number of plants appearing above ground on the coarse sand. The size of fertilizer particles apparently did not affect germination on the sandy clay loam. These results are given in Table 10.

TABLE 10.—*Number of cotton plants appearing above ground per 50-foot row for different average sizes of particles of 4–8–4 fertilizer applied at the rate of 800 pounds per acre in 1.75-inch band 2 inches below the seed*

Description of fertilizer		Ruston fine sandy loam		Norfolk coarse sand			Cecil sandy clay loam		
Preparation	Average particle diameter	May 3	May 6	May 14	May 19	June 2	May 14	May 16	May 28
	Millimeters								
FERTILIZER APPLIED AND SEED PLANTED SIMULTANEOUSLY WITH EXPERIMENTAL COMBINATION MACHINE									
No fertilizer		242±11	332±14	503± 5	488±8	472± 9	369±4	459±9	424±6
Ordinary dry mixed	0.4	67± 7	135±10	26± 4	72±7	95± 6	379±5	407±6	432±5
Grained 10–30 mesh	1.1	75± 7	119±10	48± 7	111±8	168±16	373±6	417±3	429±4
Grained 5–8 mesh	3.0	36± 4	72± 5	54±10	110±8	117±10	365±6	416±4	416±3
FERTILIZER APPLIED WITH AUGUR-TYPE DISTRIBUTOR, SEED PLANTED WITH EXPERIMENTAL MACHINE [1]									
Grained 10–30 mesh	1.1	84±12	108±14	348± 9	376±8	396±13	(2)		
Dry mixed with granular superphosphate	2.0	140±13	187±14	323±21	262±8	399±15	(2)		

[1] Lack of control of fertilizer placement due to application in a separate operation may account for comparatively high germination records.
[2] Tests were not conducted.

CONCENTRATION

A comparison of results obtained on the fine sandy loam using placements 3, 11, and 16 (Table 7), where 800 pounds per acre of 4–8–4 fertilizer were used, with results of corresponding placements of 400 pounds per acre of 8–16–8 fertilizer in Table 8 shows no material differences in number of plants appearing aboveground. The above comparisons could not be made on the coarse sand and sandy clay loam because equivalent amounts of plant food were not applied.

THINNING

Immediately following the third germination count, plants were thinned as nearly as possible to a stand of two plants per foot. It was impossible to leave a good stand on some rows where injury to germination had been severe.

EARLY BLOOM

Daily early bloom counts were made in order to obtain an indication of the earliness of the crop. While these data are not presented, when severe injury to stand did not occur, the number of early blooms was greater where the fertilizer was placed close to the seed. There is a rather definite relation between the number of early blooms and amount of cotton open at first picking although in some cases the number of plants standing after thinning to a large extent determined the number of early blooms.

PLANT GROWTH

Early growth of cotton was poor at all of the locations. This was in part due to cool nights although there was some damage by thrips and leaf hoppers, and some from fungi. Later growths were fairly satisfactory, although the size of stalks produced was less than usual. After recovery of the crop from early unfavorable conditions, no serious injury from wilt or other recognized disease was noticed. Plant growth as measured at the time of early bloom did not differ greatly among the various fertilizer treatments on each soil.

YIELD

In considering the yields of seed cotton presented in Tables 11 to 14, inclusive, attention is called to a few cases where favored conditions were created for the rows adjacent to those having very poor stands, due to the lack of plant competition, particularly for moisture, during the unusually dry season. This may partly account for the high yields on the unfertilized rows, the No. 2 placement of the Cecil sandy clay loam (Table 11) and those in which the 200-pound per acre rate of 8–16–8 fertilizer was applied at the sides of the seed on the Ruston fine sandy loam (Table 12). The number of plats having good stands, as determined by careful examination at time of picking, have been indicated in the tables for each test, but this should not be construed to mean that all other plats had a poor stand. Stands which were only slightly broken were not classified as good. Damage from boll weevil did not materially affect the yield.

PLACEMENT

Irregular stands obtained with certain placements were in general reflected in low yields of seed cotton. The good yield obtained with certain placements that gave far from satisfactory stands deserves mention as, for example, placements Nos. 3, 7 and 16 on the fine

FIGURE 7.—Characteristics and distribution of mature cotton plants on Ruston fine sandy loam fertilized with 800 pounds per acre of a 4–8–4 mixture applied (A) in contact with the seed; (B) in bands 2.25 inches to each side of and 2 inches below the level of the seed

sandy loam. (Table 11.) The ability of a relatively poor stand of cotton, caused by injury from fertilizer at planting time, to produce a remarkably good yield of cotton has also been noted in earlier experiments. It is suggested that the high yields obtained with

TABLE 11.—*Yield of seed cotton for various placements of 800 pounds per acre of 4–8–4 fertilizer*

No.	Fertilizer placement: Description	Ruston fine sandy loam: Yield: First picking Sept. 11	Ruston fine sandy loam: Yield: Total [1]	Ruston fine sandy loam: Plats with good stand	Norfolk coarse sand: Yield: First picking Sept. 4	Norfolk coarse sand: Yield: Second picking Sept. 25	Norfolk coarse sand: Yield: Total [2]	Norfolk coarse sand: Plats with good stand	Cecil sandy clay loam: Yield: First picking Sept. 23	Cecil sandy clay loam: Yield: Second picking Oct. 13	Cecil sandy clay loam: Yield: Total [3]	Cecil sandy clay loam: Plats with good stand
		Pounds per acre	*Pounds per acre*	*Number*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Number*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Number*
	No fertilizer	896	1,089±45	12	37	37	81±8	12	156	501	858±53	10
1	In contact with seed	269	604±61	0	10	97	132±15	0	80	265	514±87	0
2	1.75-inch band 1 inch below seed	473	967±89	0	64	167	263±35	0	485	680	1,377±41	10
3	2 inches below seed	874	1,376±77	2	57	224	324±23	0	441	607	1,239±34	10
4	3 inches below seed	972	1,406±72	4	138	274	446±27	5	438	564	1,195±22	10
5	4 inches below seed	852	1,249±74	5	188	261	468±26	10	[4]			
6	3.25-inch band 1 inch below seed	660	1,086±63	2	70	205	311±30	0	413	564	1,174±30	10
7	2 inches below seed	975	1,400±77	6	56	206	303±25	0	385	565	1,124±27	10
8	3 inches below seed	994	1,328±72	6	151	297	477±28	6	377	564	1,121±26	10
9	4 inches below seed	1,083	1,434±61	11	235	247	496±22	12	[4]			
10	Bands 2.25 inches to each side—											
	1 inch below level of seed [5]	1,215	1,410±36	12	262	231	502±24	12	427	544	1,141±25	10
11	2 inches below level of seed	1,348	1,502±38	12	257	251	516±22	12	429	563	1,188±35	10
12	3 inches below level of seed	1,404	1,648±56	12	227	276	515±18	12	389	564	1,129±41	10
13	Bands 3.75 inches to each side—											
	1 inch below level of seed	1,336	1,593±34	11	221	211	441±26	12	359	487	1,031±36	10
14	2 inches below level of seed	1,379	1,555±59	12	252	242	504±23	12	327	534	1,042±39	10
15	3 inches below level of seed	1,183	1,384±53	12	191	311	518±24	12	309	526	1,008±48	10
16	Mixed with soil below seed	1,049	1,394±29	8	139	235	401±14	5	342	402	1,020±30	10
17	One-half placement No. 2	976	1,394±37	3	149	282	452±28	8	[4]			
	One-half side dressed [5]											
18	One-half placement No. 3	1,116	1,497±39	10	148	313	486±32	4	[4]			
	One-half side dressed [5]											

[1] Second picking, Oct. 9.
[2] Third picking, Oct. 6.
[3] Third picking, Nov. 6.
[4] Tests were not conducted.
[5] Side dressed at thinning in bands 1.75 inches wide at a depth of 2 inches and 6 inches to each side of row.

broken stands caused by injury from fertilizer may be explained, in part, as a sort of selection of stronger germinating seeds or more vigorous plants.

The type of plants and their fruiting characteristics when grown on Ruston fine sandy loam and on Norfolk coarse sand, with the fertilizer placed in contact with the seed where a poor stand prevailed and with the fertilizer placed at the sides of the seed where a good

FIGURE 8.—Characteristics and distribution of mature cotton plants on Ruston fine sandy loam fertilized with 800 pounds per acre of 4–8–4 mixture applied (A) in 1.75-inch band 1 inch below the seed; (B) in a 1.75-inch band 3 inches below the seed

stand prevailed are shown in Figure 7. Figure 8 shows cotton grown on Ruston fine sandy loam with the fertilizer placed at different depths below the seed.

There are strong indications that fertilizer should be placed as close to the seed as possible without serious injury to germination. On the Cecil sandy clay loam where differences in stand were not a factor affecting yields except in the case of fertilizer applied in con-

tact with the seed, it is evident that close placement of fertilizer is desirable both when placed below and when placed at the sides of the seed. Localization of the fertilizer in the narrower band is indicated as desirable on this soil under the prevailing conditions. On the heavier soil, applying the fertilizer in bands below the seed gave slightly higher yields than applications to each side of the seed. On the lighter soils applications at the sides of the seed gave highest yields. Better stands, where the fertilizer was applied at the sides of the seed, were in a large measure responsible for the higher yields on the lighter-textured soils. This becomes more evident when the yields of only the plats where the stand was good are considered.

The large percentage of the total crop open at first picking on the Ruston fine sandy loam where the fertilizer was applied at the sides of the seed is of interest.

A comparison of placements Nos. 17 and 18 with placements Nos. 2 and 3 indicate that while the cotton planter continues to use present equipment, which applies the fertilizer below the seed, there may be an advantage in splitting the application of mixed fertilizer where large amounts are used on the lighter-textured soils.

RATE OF APPLICATION

The importance of employment of satisfactory methods of application where heavy applications of fertilizer are used is indicated in Table 12. On the lighter soils reduction in yield from the heaviest rate of application of fertilizer is shown where the fertilizer was applied below the seed, and where mixed with the soil, and no increase in yield was obtained on the heavier soil where these placements were used. Low yields from the heaviest applications would be expected where the stand was especially poor. Although the stand was considerably reduced by the medium rate of application, on the Ruston fine sandy loam the injury to stand was not sufficient to offset improvement in yield due to additional plant food. Highest yields were obtained where the fertilizer was applied at the sides of the seed and small increases in yield were obtained on two of the soils with the heaviest application when the fertilizer was applied in this manner. Attention has been called to the fact that the 200-pound rate of fertilizer applied in bands 2.25 inches to each side of the seed which gave an exceptionally high yield was favored by the lack of plant competition due to poor stand on an adjoining row where 600 pounds of fertilizer were applied in a band 2 inches below the seed on the Ruston fine sandy loam. Eight of the twelve plats did not show such a high yield for the test mentioned.

TABLE 12.—*Yield of seed cotton for different placements and rates of application of 8–16–8 and 5–15–4 fertilizers*

Fertilizer placement	Application rate per acre	Ruston fine sandy loam, grained 8–16–8			Norfolk coarse sand, commercial 5–15–4				Cecil sandy clay loam, commercial 5–15–4			
		Yield		Plats with good stand	Yield			Plats with good stand	Yield			Plats with good stand
		First picking Sept. 11	Total [1]		First picking Sept. 4	Second picking Sept. 25	Total [2]		First picking Sept. 23	Second picking Oct. 13	Total [3]	
	Pounds	*Pounds per acre*	*Pounds per acre*	*Number*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Number*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Number*
No fertilizer		767	922±36	12	58	62	123±13	12	133	384	679±15	10
1.75-inch band, 2 inches below seed	200	1,055	1,340±36	10	105	117	233±24	4	355	441	946±48	10
Do	400	990	1,531±86	4	47	122	192±22	0	369	464	996±52	10
Do	600	367	785±80	0	42	127	189±41	0	278	532	994±54	10
Bands 2.25 inches to each side, 2 inches below level of seed	200	1,457	1,742±81	12	180	105	290±20	12	322	442	899±41	10
Do	400	1,324	1,556±57	12	212	177	393±19	12	377	461	980±36	10
Do	600	1,182	1,557±99	11	171	255	441±29	11	356	524	1,040±31	10
Mixed with soil below seed	200	1,072	1,277±39	9	149	120	275±16	11	331	446	901±32	10
Do	400	794	1,357±77	4	81	210	314±16	1	349	475	973±33	10
Do	600	378	987±67	0	43	214	299±18	0	315	466	942±28	10

[1] Second picking, Oct. 9.

[2] Third picking, Oct. 6.

[3] Third picking, Nov. 6.

IRREGULAR DISTRIBUTION

The influence of irregular distribution of the fertilizer along the row on yield of seed cotton is shown in Table 13. The most convincing data were obtained on the Cecil sandy clay loam where differences in stand were not a factor. Here the advantage of uniform distribution is clearly shown. Pearson's correlation cofficient r between yield and coefficient of variation V in this case is -0.926 ± 0.048. The size of this coefficient indicates that the differences in yield were caused almost entirely by differences in the variability of fertilizer distribution. It will be recalled that the placement used in connection with this study did not give satisfactory stands on the lighter-textured soils and that more plants appeared aboveground where the fertilizer was distributed irregularly so that differences in stand have tended to obscure the effect of irregular distribution on yield at these locations.

TABLE 13.—*Yield of seed cotton for different degrees of irregular distribution of 800 pounds per acre of 4–8–4 fertilizer applied in 1.75-inch band 2 inches below the seed*

Coefficient (*V*) of variability of distribution [1]	Ruston fine sandy loam			Norfolk coarse sand				Cecil sandy clay loam			
	Yield		Plats with good stands	Yield			Plats with good stands	Yield			Plats with good stands
	First picking Sept. 11	Total [2]		First picking Sept. 4	Second picking Sept. 25	Total [3]		First picking Sept. 23	Second picking Oct. 13	Total [4]	
	Pounds per acre	*Pounds per acre*	*Number*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Number*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Number*
No fertilizer	882	1,054±35	12	26	35	66±10	12	211	496	915±64	10
10	874	1,377±77	6	81	249	373±31	0	441	607	1,239±34	10
17	703	1,205±83	3	164	255	460±27	0	[5]			
24	668	1,207±78	2	168	279	471±32	4	[5]			
45	664	1,210±62	2	143	274	441±29	1	405	550	1,145±32	10
55	[5]			150	269	443±31	0	401	556	1,140±46	10
62	683	1,235±44	0	88	226	359±19	0	383	484	1,044±32	10

[1] Based on 1-foot intervals. [2] Second picking, Oct. 9. [3] Third picking, Oct. 6. [4] Third picking, Nov. 6. [5] Tests were not conducted.

The value of r obtained with results from the fine sandy loam and coarse sand are -0.445 ± 0.241 and -0.214 ± 0.263, respectively. Although not very marked, the minus values in both cases indicate a relationship. However, eliminating only the test where $V = 10$ on the Norfolk coarse sand which had a number of plats with very poor stands r becomes -0.782 ± 0.116.

SIZE OF PARTICLE

Results shown in Table 14 indicate that the size of the fertilizer particle may be a factor affecting the efficiency of a fertilizer. It appears that the grained 10–30 mesh size was preferable for this fertilizer under the three sets of conditions used. This may be due to the superphosphate being more protected from the soil colloids in the grained product than in the dry-mixed fertilizer where it occurred as very fine particles. Berthault (*1*) in 1900 pointed out that superphosphate was more efficient in increasing crop yields when it was localized in the soil. It might be argued that in 5–8 mesh particles the superphosphate would be still further removed from the reverting influence of the soil, but on the other hand one or more of the ingredients of particles so large might be very slow in completely dissolving and thus be too slowly available to the plant. As will be seen in Table 14, the dry-mixed fertilizer was superior to the grained when the superphosphate used in it was composed of granular material only. On the Cecil sandy clay loam, poor stands were not a factor affecting yield except where the fertilizer was placed in contact with the seed. As shown in Table 11, for this type of soil placement No. 16 was inferior to all other placements having a good stand, with one exception. This also may be due to more reversion of superphosphate taking place when the fertilizer was mixed with the soil.

TABLE 14.—*Yield of seed cotton for different average sizes of particles of 4–8–4 fertilizer applied at the rate of 800 pounds per acre in 1.75-inch band, 2 inches below the seed*

Fertilizer description		Ruston fine sandy loam (yield)		Norfolk coarse sand (yield)			Cecil sandy clay loam (yield)		
Preparation	Average particle size	First picking Sept. 11	Total [1]	First picking Sept. 16	Second picking Sept. 25	Total [2]	First picking Sept. 23	Second picking Oct. 13	Total [3]
	Millimeters	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*
FERTILIZER APPLIED AND SEED PLANTED SIMULTANEOUSLY WITH EXPERIMENTAL COMBINATION MACHINE									
No fertilizer		321±17	407±15	15± 3	37±8	62±12	45±13	286±61	531±100
Ordinary dry mixed	0.4	690±72	1,062±89	186±17	60±6	284±17	354±33	559±19	1,099±47
Grained 10–30 mesh	1.1	737±66	1,123±74	195±19	62±4	303±18	331±43	579±25	1,109±56
Grained 5–8 mesh	3.0	549±57	841±62	129± 8	58±4	229±12	328±35	554±17	1,088±43
FERTILIZER APPLIED WITH AUGER TYPE DISTRIBUTOR, SEED PLANTED WITH EXPERIMENTAL MACHINE [4]									
Grained 10–30 mesh	1.1	521±46	775±50	195±17	48±4	266±18	([5])	----------	----------
Dry mixed with granular superphosphate	2.0	617±31	853±45	234±19	56±6	315±23	([5])	----------	----------

[1] Second picking, Oct. 9.
[2] Third picking, Oct. 6.
[3] Third picking, Nov. 6.
[4] Placement of fertilizer could not be accurately controlled by application in a separate operation.
[5] Tests were not conducted.

CONCENTRATION

A comparison of results obtained on the fine sandy loam using placement Nos. 3, 11 and 16, (Table 11) where 800 pounds per acre of 4–8–4 fertilizer were used, with results of corresponding placements of 400 pounds per acre of 8–16–8 fertilizer in Table 12, shows no significant differences in yields. The difference for placement No. 3 is only twice the probable error, while for placements Nos. 11 and 16 differences are no greater than the probable error and are in opposite directions.

SUMMARY

Under the favorable moisture conditions prevailing at time of germination on the Cecil sandy clay loam, all methods of application used resulted in satisfactory stands of cotton with the exception of the fertilizer in immediate contact with the seed.

On the Ruston fine sandy loam, with unfavorable moisture conditions, fertilizer applied at a depth of 3 inches or less below the seed caused considerable injury to germination, being more severe at the shallower depths and extremely so where the fertilizer was in contact with the seed. A delay in appearance of plants aboveground was observed where the fertilizer was placed 4 inches below the seed. With all placements at the sides of the seed, plants appeared aboveground as rapidly and in as large numbers as on the unfertilized rows.

On the Norfolk coarse sand with rather favorable moisture conditions, the effect of fertilizer placement on germination was similar to that on the fine sandy loam above mentioned.

Increasing the rate of application of a high-analysis fertilizer from 200 to 400, or 600 pounds per acre resulted in no appreciable effect upon stands on the Cecil sandy clay loam. The increase in rate of application was attended by injury to stand on the Ruston fine sandy loam and the Norfolk coarse sand where fertilizer was applied in a 1.75-inch band 2 inches below the seed and where it was mixed with the soil although no effect upon stand was noticed where the fertilizer was applied at the sides of the seed.

Irregular distribution of the fertilizer at a placement that did not give a satisfactory stand when the fertilizer was uniformly distributed along the row resulted in the appearance of a larger number of plants aboveground than where regular distribution was obtained. These plants, however, were irregularly distributed along the row and resulted in a less uniformly spaced stand.

The ability of a poor stand of cotton, caused by injury from fertilizer, to produce a good yield may be due in part to inhibition of germination of weak seeds and growths of weak seedlings so that only the more vigorous plants remain when thinned to a stand. A degree of injury to germination may be desirable if final stand is not seriously impaired.

Greatest yields were obtained with the fertilizer placed closest to the seed, when injury to germination was not serious. The distance between seed and fertilizer for best results will depend upon factors such as character and moisture content of the soil and climatic conditions.

Application of fertilizer in bands on each side of the seed gave best yields on the lighter-textured soils while applications in narrow bands below the seed gave best results on the sandy clay loam. On

the Cecil sandy clay loam, mixing the fertilizer with the soil, as accomplished in these tests did not increase the yield of seed cotton.

Where fertilizer is applied below the seed as is now commonly practiced, beneficial results seem to follow from the application of a portion of the mixed fertilizer at planting time, and the remainder as a side dressing after chopping where large amounts are used on light-textured soils.

Irregular distribution of fertilizer resulted in decreased yield of seed cotton.

Size of fertilizer particles appears to be a factor in the efficiency of a fertilizer. Localization of the superphosphate through the use of granular material is indicated as desirable.

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